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(54) **Electricity generating system**

(57) An electricity generating system includes a water tank 31 with electric heating elements (21, Fig. 4), connected to the water cooling system of an engine 12, which is heated by excess output of the system. Power in excess of that required by a load 5, which is generated by a wind turbine driven generator 2, runs up a flywheel 6 and further excess is absorbed in the tank 31. A fan (19, Fig. 4) associated with a radiator (17) connected to the tank 31 may be operated to dissipate further excess power. When the load requirements exceed the output of the generators 2 and 7 the engine 12 operates the generator 13.

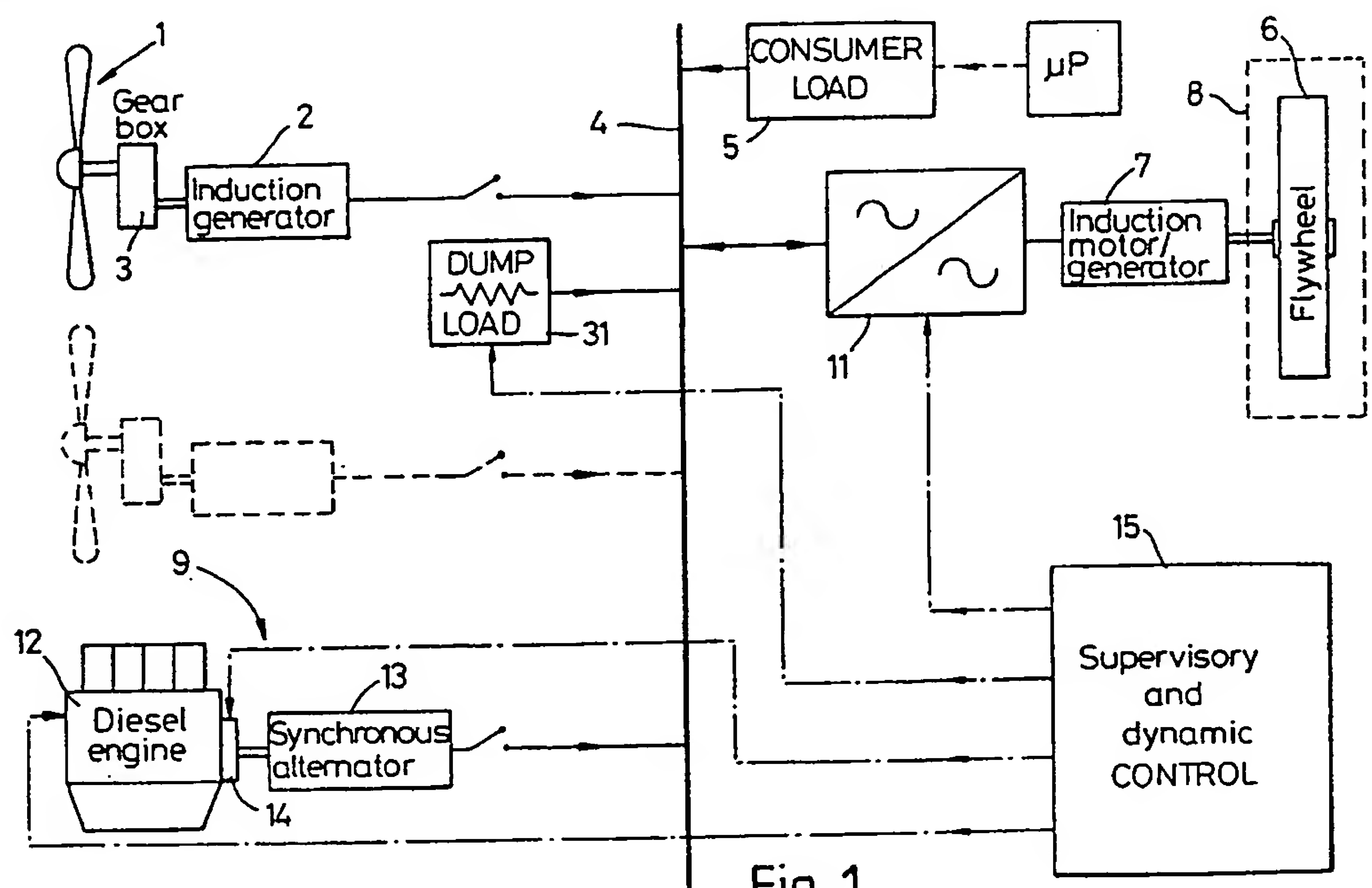

Fig. 1

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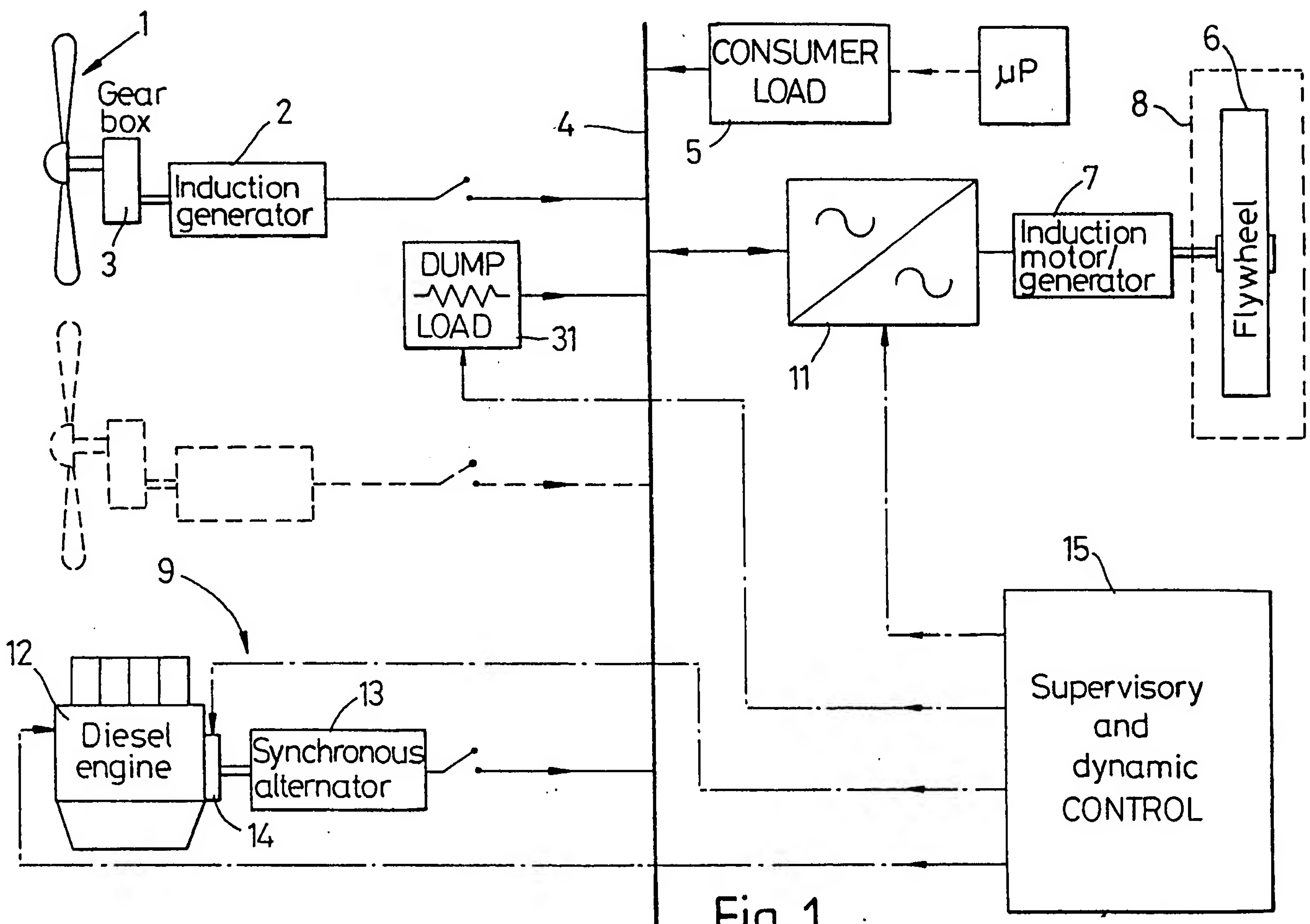
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.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CONSUMER LOAD
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µP
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Flywheel
7
Induction motor/ generator
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DUMP LOAD
31
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12
Diesel engine
13
Synchronous alternator
14
15
Supervisory and dynamic CONTROL

Fig. 1

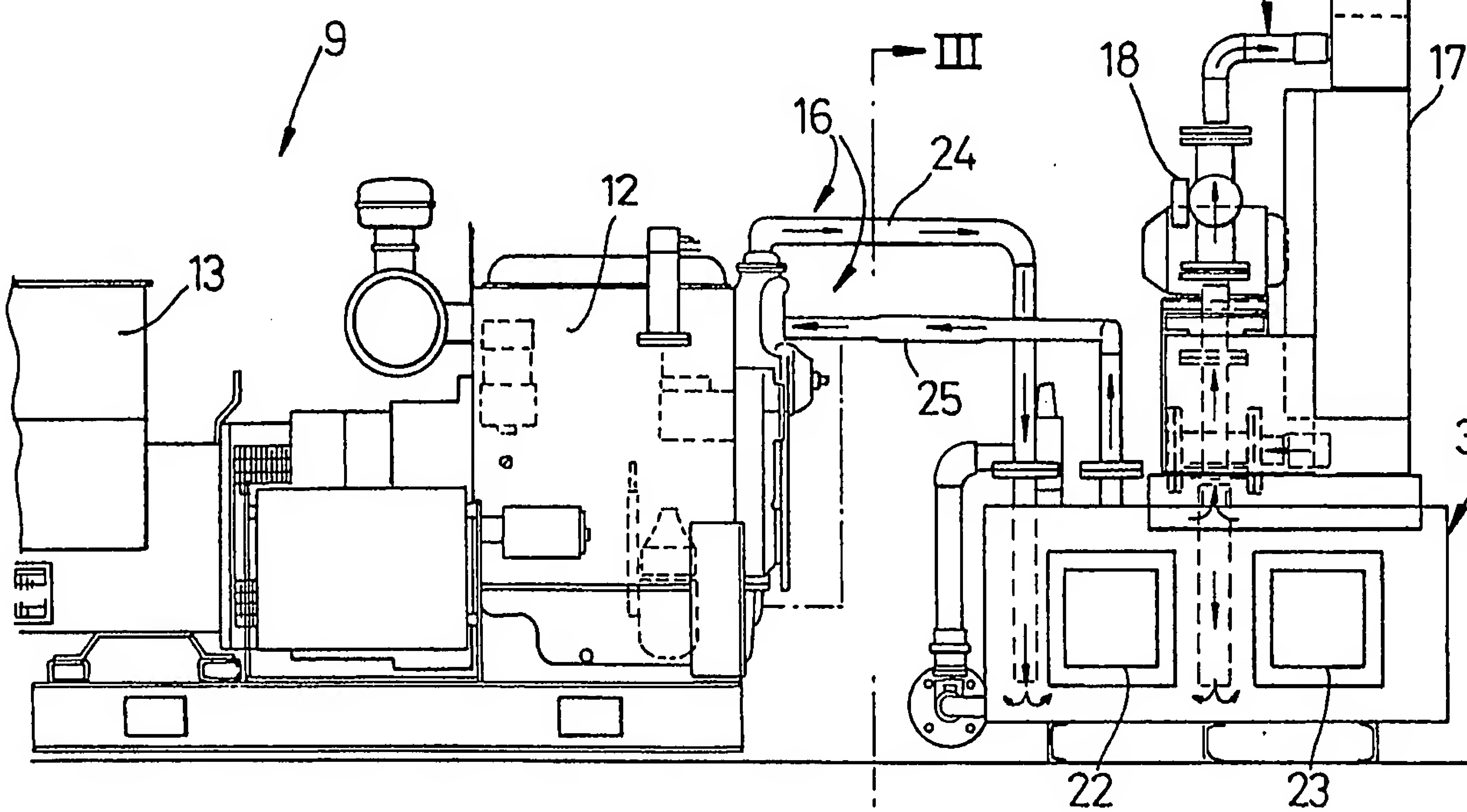

Fig. 2

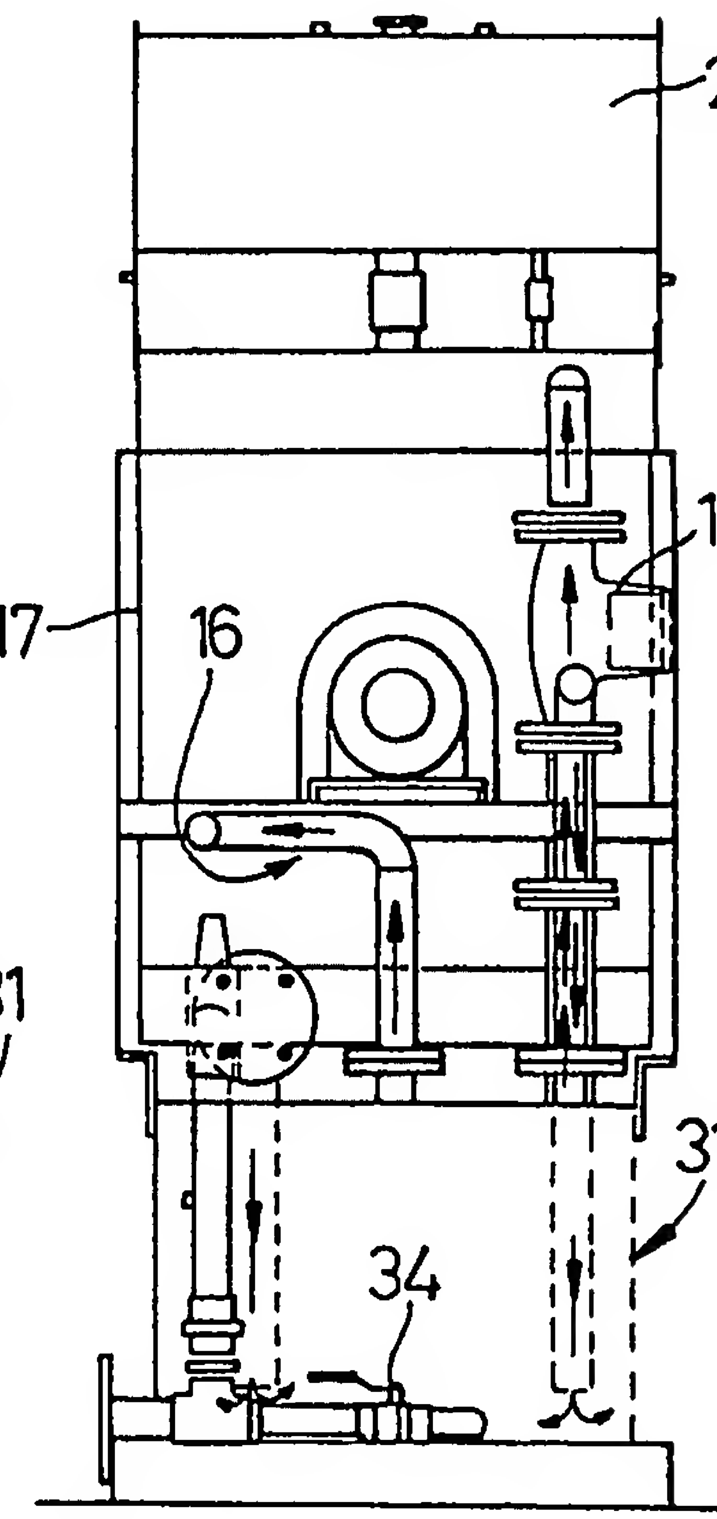

Fig. 3

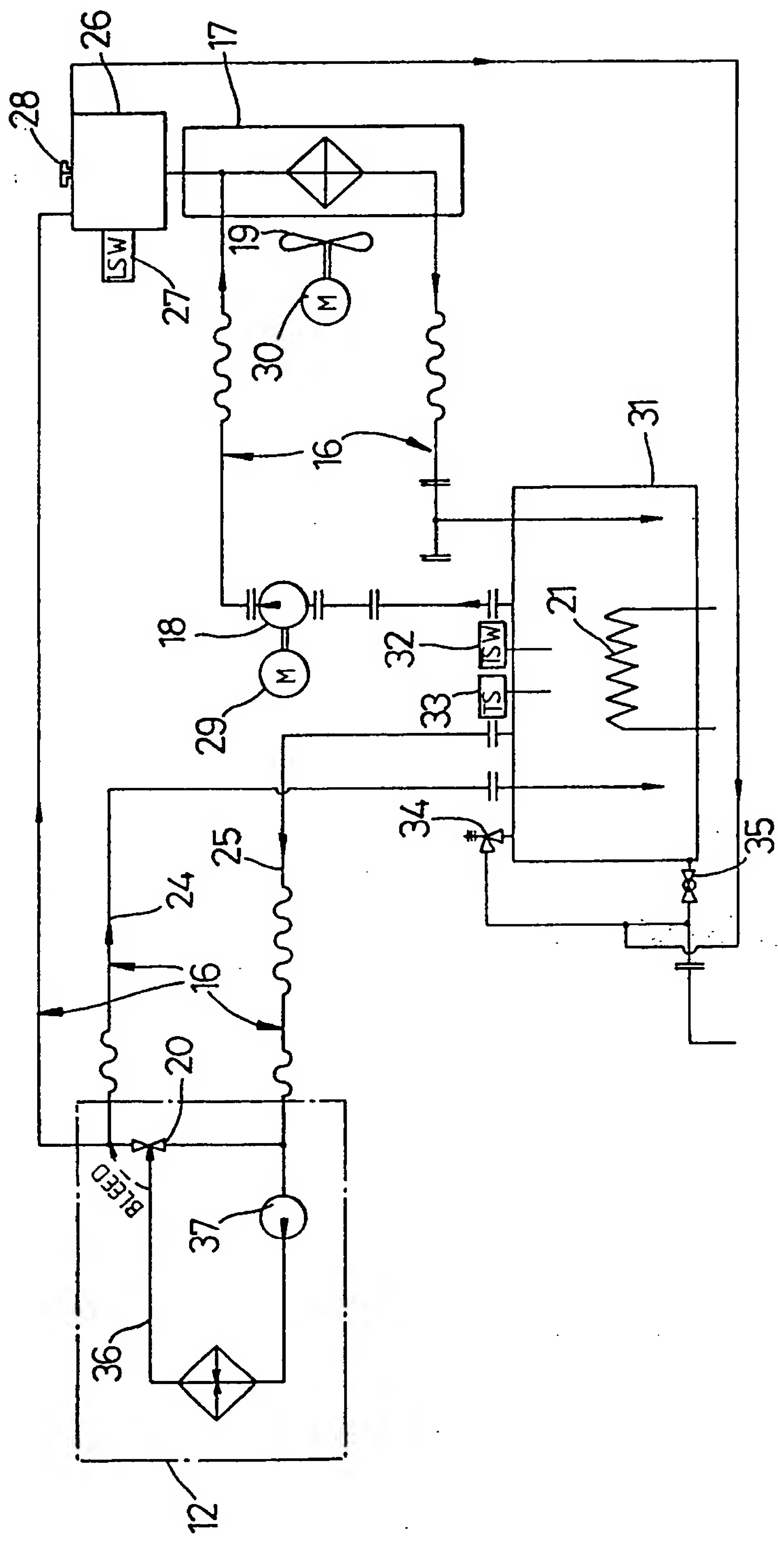
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Fig. 4

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ELECTRICITY GENERATING SYSTEM

This invention relates to an electricity generating system, and in particular to a diesel generator set/flywheel system, capable of operating independently of the grid and particularly, though not exclusively employing wind as the prime energy source powering a wind turbine generator.

The advantages of employing a flywheel as an energy buffer in a generating system, particularly a wind powered system are already known - viz the flywheel serves to absorb excess wind energy when available and to release it when the wind drops, thereby avoiding the need to run the diesel engine - with consequent fuel savings - until such time as the energy stored in the flywheel has been exhausted to provide an auxiliary generating capacity to match consumer load, while the flywheel assists in maintaining continuity of supply given the finite start-up time of a diesel generator set. Furthermore the on/off cycling of the diesel generator set (primarily due to wind turbulance) is generally reduced resulting in less wear and longer service life. It follows that there will be circumstances where the flywheel has been run up to maximum speed and surplus wind energy is still available which must be dumped and heat dissipation offers a ready solution.

It is of course necessary to provide a control system to maintain continuity of supply and frequency control irespective of wind conditions and consumer demand.

According to a first aspect of the present invention,

there is provided an electricity generating system comprising:-

(i) a diesel engine powered generator set; and

(ii) an electrical dump load,

with the dump load being employed primarily to heat the liquid coolant of the diesel engine of the generator set, so as to pre-heat the engine.

Preferably, the system also comprises a wind turbine generator, with the diesel generator set being brought into use only when the wind energy is insufficient to generate sufficient power to meet consumer load.

Thus, with the employment of the dump load to pre-heat the coolant and hence the engine,

(i) the engine is easier to start and can more rapidly be brought up to full load to provide full generating capacity with the minimum of delay; and

(ii) it reduces the level of soot emissions during start up.

Furthermore, if dump load energy is still available after the coolant, usually water, has been raised to the maximum temperature desired, then in accordance with another feature of the invention, the heated coolant may be circulated to some external system where the thermal energy could be put to some use, e.g. for background heating, before it reaches the radiator of the diesel engine or is returned directly to tank, suitable controls being provided in either case. Thus, converting the surplus wind energy to thermal energy of the

liquid coolant puts it in a readily available form for heating applications such as background heating. The heat collected by the engine cooling water when the engine is running which - would otherwise be wasted - is also available for the same purpose.

Preferably, the system also includes an energy buffer, which is preferably in the form of a flywheel drivable by the turbine when excess wind energy and hence generating capacity is available beyond consumer load, with the diesel generator set being brought into use when the flywheel energy has been exhausted.

Preferably, the electrical dump load comprises a number of heating elements carried on two loadbanks, which are mounted in the side of the dump load tank.

It is convenient, for control purposes, for the number and rating of the heating elements to be selected so they can form the steps of a binary sequence, the reason being that an overall system controller will decide, at any instant, how much power needs to be dumped and express this as a binary signal. By grouping the heating elements together so that each step corresponds to one of the bits of the binary signal the required amount of dump load can be energised automatically, using solid state relays. These are chosen for their reliability in view of the high number of switching operations that are expected.

The layout of the heating elements on the two loadbanks is designed to ensure that whenever surplus energy (i.e. heat) is available it can be readily transferred to the

engine.

For this reason the first portion of any dumped power is directed to the heating elements in the top half of a first loadbank, raising the temperature of the surrounding water. This hot water is induced to circulate around the diesel engine water jacket by natural convection - though it could be driven by a pump - returning to the tank at a low level.

As the bulk temperature of the water in the tank rises, caused either by a continuing surplus of wind energy or because the diesel engine is running, an electric circulating pump may be energised to pass the hot water through the radiator where the heat is disspated to the atmosphere, aided if necessary by the electrically operated radiator fan.

One embodiment of the invention is shown in greater detail, by way of example, in the accompanying drawings, in which:-

Figure 1 is a schematic layout of a wind powered electricity generating system in accordance with the invention;

Figure 2 is a side elevation of the diesel engine and dump tank of Figure 1;

Figure 3 is a section on the line III-III of Figure 2; and

Figure 4 is a schematic diagram of the cooling system of Figures 2 and 3.

In Figure 1, a three-bladed fixed pitch wind turbine 1, drives an induction generator 2 via a gearbox 3. The turbine 1 has a stall regulated rotor and the induction

generator 2 is equipped with a soft start mechanism to reduce paralleling transients, the generator 2 supplying power to a 50 HZ grid 4, with consumer load indicated at 5.

Due to the variability of the wind, the output from the wind turbine 1 fluctuates rapidly and consequently may frequently exceed the load demand, while moments later a shortfall of power may occur. Consequently, when surplus power is buffered via a flywheel 6 operated through a variable speed drive motor 7, the flywheel 6 consisting of a laminated steel disk running in an evacuated housing 8 to reduce windage losses. At its maximum operating speed of 6000 r/min the flywheel provides a storage capacity of 12 MJ, sufficient to supply the average system load for up to 5 minutes and, in a power shortfall situation, providing a first means of supplementing energy supply to the grid 4. However, as the storage capacity of the flywheel 6 is finite, a second supplementary supply means is provided in the form of a diesel generator set 9.

Energy transfer to and from the flywheel 6 is accomplished through a directly coupled induction motor/generator 10 connected to the grid 4 via an electronic variable speed drive. To match the maximum flywheel speed of 6000R/min a 2-pole motor is used, operating with a supply frequency of up to 100Hz.

For the conversion of power surplus or deficit from the grid 4 into a variable frequency supply for the motor, a standard industrial current-source inverter 11 is used. The drive includes features to ensure thyristor commutation at

high motor speeds and/or no-load operation and has supervisory control for a safe shutdown in the case of overload or collapse of the grid voltage.

The diesel generator set 9 comprises a 55kW turbo-charged, water cooled diesel engine 12 coupled to an 85kVA/70kW synchronous generator 13 through an electro-magnetic clutch 14. A controller 15 is utilised to control the diesel generator set 9 and its associated equipment under all operating conditions including engine start-up and shut-down and clutch operation. The controller 15 continuously monitors and displays a range of parameters and set points for the diesel generator set 9 and ensures safe shut-down in the case of system malfunction. The controller 15 is also capable of altering set-points and timers via a key-pad and to modify the logic control programme via a communications link, and hence to be suitable for tailoring the response of the diesel generator set 9 to the requirements of a wind/diesel system.

The engine cooling system is detailed in Figures 2 to 4 and incorporates an external circuit 16 consisting basically of a high capacity radiator 17, a circulating pump 18 and fan 19. Associated with radiator 17 is a header tank 26 having a level switch 27 and a pressure cap 28 set at 10psi, while an electric motor 29 drives the pump 18 and another electric motor 30 drives the the fan 19. The pump 18 and fan 19 are switched on by the controller 15 only when the coolant reaches prescribed upper temperature levels, thus avoiding pump and fan losses and engine overcooling at low loads. Consequently

this improves fuel consumption and reduces engine wear under the load conditions likely to prevail in wind/diesel operation. The internal thermostatic by-pass valve 20 enables quick warming up of the engine 12 after start-up, which further reduced engine wear.

Since the putput of a fixed-speed, stall-regulated wind turbine cannot be controlled to every desired level, a situation may well arise where the wind power exceeds the demand load during prolonged periods. Thus, when the diesel engine is stopped and the fly wheel energy store is fully charged, excess power must be diverted to prevent an unacceptable frequency rise. For this reason a fast response electrical dump load in the form of a 200 litre coolant (water) tank 31, with a maximum power of 72kW, is incorporated in the system, consisting of binary, resistive load steps with a smallest increment of 1.1 kW. To reduce the cost of this component and to put the dissipated energy to good use the dump load is, in accordance with the invention, integrated with the engine cooling system, thereby serving a dual purpose. The dump load tank 31 is also being provided with a temperature 4 switch 32 set at $102^{o}c$, a temperature sender 33 to the controller 15, a relief valve 34, and a ball valve 35 for tank drainage purposes.

In detail, the electrical dump load comprises a number of electrical heating elements 21 carried on two load banks 22, 23 which are mounted in the side of the dump load tank 31. The engine 12 has a water jacket 36, and a mechanically driven water pump 37, and is connected by lagged inlet fluid coolant

pipes 24 and 25 to the dump load tank 31. The number and rating of the heating elements 21 is selected to form the steps of a binary sequence whereby the contoller 15 decides, at any instant how much power needs to be dumped, and to express this as a binary signal. Consequently, the heating elements 21 are grouped together so that each step corresponds to one of the bits of the binary signal, so that the required amount of dump load can be energised automatically, using solid state relays.

When the engine is switched off, the radiator 17, fan 19 and pump 18 of the external cooling circuit 16 are used to dissipate any excess heat from the dump load. At the same time the heated coolant is circulated through the engine to provide favourable start-up conditions when the diesel engine is called upon, operation of the pump and fan under these conditions again being controlled by the controller 15.

CLAIMS

1. An electricity generating system comprising:-

(i) a diesel engine powered generator set; and

(ii) an electrical dump load,

with the dump load being employed primarily to heat the liquid coolant of the diesel engine of the generator set, so as to pre-heat the engine.

2. A system as claimed in Claim 1, comprising a wind turbine generator with the diesel generator set being brought into use only when the wind energy is insufficient to generate sufficient power to meet consumer load.

3. A system as claimed in Claim 1 or Claim 2, including an energy buffer.

4. A system as claimed in Claim 3, wherein the buffer is in the form of a flywheel drivable by the turbine when excess wind energy and hence generating capacity is available beyond consumer load, with the diesel generator set being brought into use when the flywheel energy has been exhausted.

5. A system as claimed in any preceding Claim, wherein the electrical dump load comprises a number of heating elements carried on two loadbanks, which are mounted in the side of the dump load tank.

6. A system as claimed in Claim 5 wherein, for control purposes, the number and rating of the heating elements is selected so they form the steps of a binary sequence, with an overall system controller deciding, at any instant, how much power needs to be dumped and express this as

a binary signal.

7. A system as claimed in Claim 6, wherein the heating elements are grouped together so that each step corresponds to one of the bits of the binary signal and hence the required amount of dump load can be energised automatically, using solid state relays.

8. A system as claimed in Claim 5 and any claim appendant thereto, wherein the first portion of any dumped power is directed to the heating elements in the top half of a first loadbank, raising the temperature of the surrounding water, with this hot water induced to circulate around the diesel engine water jacket by natural convection - or driven by a pump - returning to the tank at a low level.

9. A system as claimed in Claim 8, wherein as the bulk temperature of the water in the tank rises, caused either by a continuing surplus of wind energy or because the diesel engine is running, an electric circulating pump may be energised to pass the hot water through the radiator where the heat is disspated to the atmosphere, aided if necessary by the electrically operated radiator fan.

10. An electricity generating system substantially as hereinbefore described with reference to the accompanying drawings.

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